California Air Resources Board

Quantification Methodology

California Energy Commission
Low Carbon Fuel Production Program

California Climate Investments

Note:
The California Air Resources Board (CARB) is accepting public comments on the Draft Low Carbon Fuel Production Program (LCFPP) Benefits Calculator Tool and the Draft LCFPP Quantification Methodology until March 22, 2019 via GGRFProgram@arb.ca.gov. The Draft Benefits Calculator Tool and Draft Quantification Methodology are subject to change pending stakeholder comments and Final LCFPP Guidelines. The Final LCFPP Benefits Calculator Tool and Final LCFPP Quantification Methodology will be available on the California Climate Investments resources webpage at: http://www.arb.ca.gov/cci-resources.

DRAFT
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Table of Contents

Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (GHG) emission reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as "priority populations." Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefits calculator tools. CARB develops these methodologies and tools based on the project types eligible for funding by each administering agency, as reflected in the program expenditure records available at: www.arb.ca.gov/cci-expenditurerecords.

For the California Energy Commission (CEC) Low Carbon Fuel Production Program (LCFPP), CARB staff developed this LCFPP Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project type. This methodology uses calculations to estimate GHG emission reductions from alternative fuel production which displaces the use of petroleum-based fuels, and avoided GHG emissions from reduced onsite grid electricity and natural gas usage and other improvements to existing operations.

The LCFPP Benefits Calculator Tool automates methods described in this document, provides a link to a step-by-step user guide with a project example, and outlines documentation requirements. Projects will report the total project GHG emission reductions and co-benefits estimated using the LCFPP Benefits Calculator Tool as well as the total project GHG emission reductions per dollar of GGRF funds requested. The LCFPP Benefits Calculator Tool is available for download at: http://www.arb.ca.gov/cci-resources.

Using many of the same inputs required to estimate GHG emission reductions, the LCFPP Benefits Calculator Tool estimates the following co-benefits and key variables from LCFPP projects: fossil fuel use reductions (gallons), renewable fuel production (gallons), fossil fuel energy use reductions (kWh or therms), renewable energy generation (kWh), and material diverted from landfill (tons). Key variables are project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., renewable energy generated). Additional co-benefits for which CARB assessment methodologies were not incorporated into the LCFPP Benefits Calculator Tool may also be applicable to the project. Applicants should consult the LCFPP guidelines, solicitation materials, and agreements to ensure they are meeting LCFPP requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB and CEC developed this LCFPP Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability, to be used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects.[1] The implementing principles ensure that the methodology would:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing and proven methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emission reduction estimates that are conservative and supported by empirical literature.

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the LCFPP project types. CARB also consulted with CEC to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

In addition, the University of California, Berkeley, in collaboration with CARB, developed assessment methodologies for a variety of co-benefits such as providing cost savings, lessening the impacts and effects of climate change, and strengthening community engagement. As they become available, co-benefit assessment methodologies are posted at: https://ww2.arb.ca.gov/resources/documents/cci-methodologies.

Tools

The LCFPP Benefits Calculator Tool relies on CARB-developed emission factors. CARB has established a single repository for emission factors used in CARB benefits calculator tools, referred to as the California Climate Investments Quantification Methodology Emission Factor Database (Database), available at: http://www.arb.ca.gov/cci-resources. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated. The emission factors related to transportation are derived from CARB's Mobile Source Emissions Inventory (EMFAC2014) and California-modified Greenhouse Gases, Regulated Emissions, and Energy use in Transportation version 3.0 (CA-GREET3.0) model.

Applicants must use the LCFPP Benefits Calculator Tool to estimate the GHG emission reductions and co-benefits of the proposed project. The LCFPP Benefits Calculator Tool can be downloaded from: http://www.arb.ca.gov/cci-resources.

[1] California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines

Section B. Methods

The following section provides details on the methods supporting emission reductions in the LCFPP Benefits Calculator Tool.

Project Types

CEC developed two project types that meets the objectives of the LCFPP and for which there are methods to quantify GHG emission reductions.[2] Other project features may be eligible for funding under the LCFPP; however, each project requesting GGRF funding must include at least one of the following:

- New Facility; and
- Facility Expansion.

General Approach

Methods used in the LCFPP Benefits Calculator Tool for estimating the GHG emission reductions and air pollutant emission co-benefits by project type are provided in this section. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

These methods account for the GHG emission reductions of a proposed LCFPP project based on avoided carbon dioxide (CO_2) emissions associated with displacing conventional fossil-based transportation fuels with a renewable alternative, the co-production of renewable electricity and renewable natural gas for stationary applications, and the reduction in electricity or natural gas usage from existing facility operations. In general, the GHG emission reductions are estimated in the LCFPP Benefits Calculator Tool using the approaches in Table 1. The LCFPP Benefits Calculator Tool also estimates air pollutant emission co-benefits and key variables using many of the same inputs used to estimate GHG emission reductions.

Table 1. General Approach to Quantification by Project Type

New Facility (Construct a new, commercial-scale facility for the production of ultra-low carbon transportation fuel)
GHG Emission Reductions = Emissions associated with Baseline Fuels – Emissions associated with Replacement Fuels
Facility Expansion (Install additional ultra-low carbon transportation fuel production capacity at an existing commercial-scale facility)
GHG Emission Reductions = Emissions associated with Baseline Fuels – Emissions associated with Replacement Fuels + Avoided grid electricity emissions + Avoided natural gas emissions

[2] https://www.energy.ca.gov/transportation/lowcarbonfuels/documents/

A. Emission Reductions from New Facility

Emission reductions from New Facility project types are calculated using the same equations as for Facility Expansion project types, except that avoided grid electricity emissions and avoided natural gas emissions are assumed to be zero. See the following section for equations to estimate emission reductions, which are applicable to New Facility project types.

B. Emission Reductions from Facility Expansion

To support the analysis of emission reductions from the proposed projects, staff developed a set of emission factors for a variety of different vehicle classes. The emission factors and assumptions used in the analysis were derived from a number of sources such as CARB's California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET 3.0) Model, CARB's Emission Factor (EMFAC2014) Model, information from CARB regulation staff reports and emissions inventories, publically available technical reports, and staff assumptions. GHG emission factors were developed on a well-to-wheel (WTW) basis since greenhouse gases are global pollutants. Criteria pollutant and toxic emission factors are calculated based solely on tailpipe emissions because of their localized impact.

1. Greenhouse Gas Emission Reduction Equations

The GHG emission reductions from LCFPP projects are estimated as the difference between the baseline and project scenarios using Equation 1.

Equation 1: Total Project GHG Emission Reductions

$$ER_{GHG} = \left[\sum_{i=1}^{n}\left(AAE_{baseline,i} - AE_{alt,i}\right) \times Q_i\right] + AE_{Facility,Elec} + AE_{Facility,NG}$$

Where,			Units
ER_{GHG}	=	Total GHG emission reductions from the project.	$MTCO_2e$
i	=	Primary, secondary, or tertiary transportation fuel.	[unitless]
n	=	Number of types of transportation fuels expected to be produced by the project, up to three.	[unitless]
$AAE_{baseline}$	=	Annual avoided GHG emissions of the baseline transportation fuel, relative to the replacement transportation fuel.	$MTCO_2e/yr$
AE_{alt}	=	Annual GHG emissions of the replacement alternative transportation fuel.	$MTCO_2e/yr$
Q	=	Quantification period for the production of the primary fuel, secondary fuel, and tertiary fuel, up to 5 years.	Years
$AE_{Facility,\ Elec}$	=	Avoided GHG emissions from electricity savings and renewable electricity generation at the fuel production facility.	$MTCO_2e$
$AE_{Facility,\ NG}$	=	Avoided GHG emissions from natural gas savings and renewable natural gas production at the fuel production facility.	$MTCO_2e$

GHG emission factors for transportation fuel are based upon lifecycle GHG emission calculation methodologies adopted from the Low Carbon Fuel Standard (LCFS)[3], which relies upon carbon intensities (CI) calculated using the CA-GREET 3.0 model. The GHG emission factor of the baseline transportation fuel is calculated using Equation 2. The GHG emission factor of the replacement transportation fuel is calculated using Equation 3. These equations are used for both the primary and secondary fuel.

Equation 2: Annual Avoided GHG Emissions of the Baseline Fuel

$$AAE_{baseline} = PC \times ED \times CI_{baseline} \times EER \times C_{GHG}$$

Where,			Units
$AAE_{baseline}$	=	Annual avoided GHG emissions of the baseline transportation fuel.	$MTCO_2e/yr$
PC	=	Annual production capacity of the replacement fuel.	gal/yr or therm/yr or kg/yr
ED	=	Energy density of the replacement fuel.	MJ/gal or MJ/therm or MJ/kg
$CI_{baseline}$	=	LCFS lifecycle carbon intensity of the baseline fuel.	gCO_2e/MJ
EER	=	Energy Economy Ratio of the replacement fuel, relative to the baseline fuel.	[unitless]
C_{GHG}	=	Conversion factor from units of grams to metric tons.	1 x 10^{-6} $MTCO_2e/gCO_2e$

Equation 3: Annual GHG Emissions of the Replacement Fuel

$$AE_{alt} = PC \times ED \times CI_{alt} \times C_{GHG}$$

Where,			Units
AE_{alt}	=	Annual GHG emissions of the replacement alternative transportation fuel.	$MTCO_2e/yr$
PC	=	Annual production capacity of the replacement fuel.	gal/yr or therm/yr or kg/yr
ED	=	Energy density of the replacement fuel.	MJ/gal or MJ/therm or MJ/kg
CI_{alt}	=	LCFS lifecycle carbon intensity of the replacement alternative fuel.	gCO_2e/MJ
C_{GHG}	=	Conversion factor from units of grams to metric tons.	1 x 10^{-6} $MTCO_2e/gCO_2e$

Applicants may provide their own fuel production pathway's CI number, calculated using a method consistent with CA-GREET 3.0. For baseline fuels (gasoline, diesel, or CNG) or when is the CI of the replacement fuel is not provided, staff assumed the following CI pathways for the fuels analyzed:

- Gasoline: California reformulated gasoline (CaRFG) from the LCFS Lookup Table[4];
- Diesel: Ultra low sulfur diesel (ULSD) from the LCFS Lookup Table;
- Compressed Natural Gas (CNG): Compressed natural gas from pipeline average North American fossil natural gas from the LCFS Lookup Table;

[3] https://www.arb.ca.gov/fuels/lcfs/lcfs.htm
[4] https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

- Ethanol: volume-weighted average CI of ethanol consumed in California in 2017 from LCFS Reporting Tool (LRT) data;
- Biodiesel: volume-weighted average CI of biodiesel consumed in California in 2017 from LRT data;
- Renewable Diesel (RD): volume-weighted average CI of RD consumed in California in 2017 from LRT data;
- Renewable Natural Gas (RNG): volume-weighted average CI of RNG consumed in California in 2017 from LRT data; and
- Hydrogen: SB 1505 compliant compressed hydrogen produced in California from central SMR of 33.3% biomethane from North American landfills and 66.7% North American fossil-based natural gas, based upon the LCFS Lookup Table;

Avoided GHG emissions reductions from the co-production of renewable electricity and reductions in current electricity consumption requirements at the existing facility, if applicable, are calculated using Equation 4. Emission increases from the use of electricity are incorporated into the transportation fuel pathways' lifecycle carbon intensities, and therefore do not need to be quantified separately.

Equation 4: Avoided GHG Emission Reductions from Electricity Savings and Renewable Electricity Generation for Stationary Applications

$$ER_{Facility,Elec} = (AAE_{Elec\ Gen} \times Q_{Elec}) + (AAE_{Elec\ Sav} \times L)$$

Where,			Units
$E_{Facility,\ Elec}$	=	Annual net GHG emissions from electricity consumption and production at the fuel production facility.	$MTCO_2e$
$AAE_{Elec\ Gen}$	=	Annual avoided GHG emissions from the generation of renewable electricity to displace grid electricity usage for stationary applications.	$MTCO_2e/yr$
$AAE_{Elec\ Sav}$	=	Annual avoided GHG emissions from reduced use of grid electricity for an existing facility's stationary applications.	$MTCO_2e/yr$
Q_{Elec}	=	Quantification period for the production of renewable electricity for stationary applications, up to 5 years.	Years
L	=	Project life, up to 5 years.	Years

The annual avoided GHG emissions from the generation of renewable electricity for stationary end uses is calculated using Equation 5.

Equation 5: Annual Avoided GHG Emissions from Renewable Electricity Generation for Stationary Applications

$$AAE_{Elec\ Gen} = EF_{GHG,Grid} \times P_{Elec\ Gen}$$

Where,			Units
$AAE_{Elec\ Gen}$	=	Annual avoided GHG emissions from the generation of renewable electricity to displace grid electricity usage for stationary applications.	$MTCO_2e/yr$
$EF_{GHG,\ Grid}$	=	GHG emission factor for California's electrical grid.	$MTCO_2e/kWh$
$P_{Elec\ Gen}$	=	Estimated annual renewable electricity generation at full production capacity.	kWh/yr

For "Facility Expansion" projects, GHG emissions from current facility operations may be reduced by through the implementation of more efficient equipment or operations. The avoided GHG emissions from the reduced onsite use of grid electricity is calculated using Equation 6.

For "New Facility" project types, the avoided GHG emissions from reduced electricity use are considered to be zero since there is no existing baseline operation to reduce emissions from.

Equation 6: Annual Avoided GHG Emissions from Reduced Use of Grid Electricity for Stationary Applications

$$AEE_{Elec\ Sav} = EF_{GHG,Grid} \times P_{Elec\ Sav}$$

Where,			Units
AAE_{Elec}	=	Annual avoided GHG emissions from reduced use of grid electricity for an existing facility's stationary applications.	$MTCO_2e/yr$
$EF_{GHG,\ Grid}$	=	GHG emission factor for California's electrical grid.	$MTCO_2e/kWh$
$P_{Elec\ Sav}$	=	Estimated annual reduction in existing facility operation's electricity consumption, at full production capacity.	kWh/yr

Avoided GHG emissions reductions from the co-production of renewable natural gas and reductions in current natural gas consumption requirements at the existing facility, if applicable, are calculated using Equation 7. Emission increases from the use of natural gas are incorporated into the transportation fuel pathways' lifecycle carbon intensities, and therefore do not need to be quantified separately.

Equation 7: Avoided GHG Emission Reductions from Natural Gas Savings and Renewable Natural Gas Production for Stationary Applications

$$AE_{Facility,NG} = \left(AAE_{RNG\ Gen,Offsite} \times Q_{RNG}\right) + \left(AAE_{RNG\ Gen,Onsite} \times Q_{RNG}\right) + \left(AAE_{NG\ Sav} \times L\right) + \left(AER_{RNG\ Sub} \times L\right)$$

Where,			Units
$AE_{Facility,\ NG}$	=	Avoided GHG emissions from natural gas savings and renewable natural gas production at the fuel production facility.	$MTCO_2e$
$AAE_{RNG\ Gen,\ Offsite}$	=	Annual avoided GHG emissions from the generation of renewable natural gas to displace fossil natural gas usage for offsite stationary applications.	$MTCO_2e/yr$
$AAE_{RNG\ Gen,\ Offsite}$	=	Annual avoided GHG emissions from the generation of renewable natural gas to displace fossil natural gas usage for onsite stationary applications.	$MTCO_2e/yr$
$AAE_{NG\ Sav}$	=	Annual avoided GHG emissions from reduced use of natural gas for an existing facility's stationary applications.	$MTCO_2e/yr$
$ER_{RNG\ Sub}$	=	Annual GHG emission reductions from the substitution of current natural gas usage at the existing facility with renewable natural gas.	$MTCO_2e/yr$
Q_{RNG}	=	Quantification period for the production of the renewable natural gas for stationary applications.	Years
L	=	Project life, up to 5 years.	Years

The annual avoided GHG emissions from the production of renewable natural gas for offsite stationary end uses is calculated using Equation 8.

Equation 8: Avoided GHG Emission Reductions from Renewable Natural Gas Production for Offsite Stationary Applications

$$AAE_{RNG\ Gen,Offsite} = P_{RNG\ Gen} \times (1 - R_{Onsite}) \times EF_{GHG,NG}$$

Where,			Units
$AAE_{RNG\ Gen,\ Offsite}$	=	Annual avoided GHG emissions from the generation of renewable natural gas to displace fossil natural gas usage for offsite stationary applications.	$MTCO_2e/yr$
$P_{RNG\ Gen}$	=	Estimated annual renewable natural gas production at full production capacity.	therm/yr
R_{Onsite}	=	Percentage of RNG produced for stationary applications that is expected to be used onsite at the project facility.	%
$EF_{GHG,\ NG}$	=	Average GHG emission factor for natural gas combustion.	$MTCO_2e$/therm

The annual avoided GHG emissions from the production of renewable natural gas for offsite stationary end uses is calculated using Equation 9. Calculations include avoided methane emissions, as well as avoided carbon dioxide emissions from natural gas.

Equation 9: Avoided GHG Emission Reductions from Renewable Natural Gas Production for Onsite Stationary Applications

$$AAE_{RNG\ Gen,Onsite} = P_{RNG\ Gen} \times R_{Onsite} \times \left(\frac{1}{ED_{RNG}}\right) \times \left\{\left[1 - \left(\frac{1}{\eta_{Digester}} - \eta_{Tech}\right)\right] \times 25 + \left(\frac{1}{\eta_{Digester}} - \eta_{Tech}\right) \times 2.74\right\}$$

Where,			Units
$AAE_{RNG\ Gen,\ Onsite}$	=	Annual avoided GHG emissions from the generation of renewable natural gas to displace fossil natural gas usage for onsite stationary applications.	$MTCO_2e/yr$
$P_{RNG\ Gen}$	=	Estimated annual renewable natural gas production at full production capacity.	therm/yr
R_{Onsite}	=	The percentage of renewable natural gas produced by the project for stationary applications that will be used onsite.	%
ED_{RNG}	=	Energy density of natural gas.	$therm/MTCH_4$
$\eta_{Digester}$	=	Collection efficiency of the anaerobic digester system.	%
η_{Tech}	=	Methane destruction efficiency of the electric generation equipment.	%
25	=	Global warming potential factor of methane. (Dividing by this value converts $MTCO_2e$ back to $MTCH_4$).	$MTCO_2e/ MTCH_4$
2.74	=	Molecular weight of CO_2 / molecular weight of CH_4.	$MTCO_2e/ MTCH_4$

For “Facility Expansion” projects, GHG emissions from current facility operations may be reduced by through the implementation of more efficient equipment or operations. The avoided GHG emissions from the reduced onsite use of natural gas is calculated using Equation 10.
For “New Facility” project types, the avoided GHG emissions from reduced natural gas use are considered to be zero since there is no existing baseline operation to reduce emissions from.

Equation 10: Annual Avoided GHG Emissions from Reduced Use of Natural Gas

$$AEE_{NG\ Sav} = S_{NG} \times EF_{NG}$$

Where,			Units
$AAE_{NG\ Sav}$	=	Annual avoided GHG emissions from reduced use of natural gas for stationary applications.	$MTCO_2e/yr$
S_{NG}	=	Annual onsite, stationary (non-transportation) natural gas savings.	therm/yr
EF_{NG}	=	GHG emission factor for natural gas combustion.	$MTCO_2e/therm$

For “Facility Expansion” projects, GHG emissions from current facility operations may be reduced by substituting natural gas usage with renewable natural gas. The avoided GHG emissions from the reduced onsite use of natural gas is calculated using Equation 11**Equation 11**.

Equation 11: Annual Avoided GHG Emissions from Substituting Natural Gas

$$ER_{RNG\ Sub} = Sub_{NG} \times EF_{NG}$$

Where,			Units
$AAE_{NG\ Sav}$	=	Annual avoided GHG emissions from reduced use of natural gas for stationary applications.	$MTCO_2e/yr$
Sub_{NG}	=	Annual amount of renewable natural gas that will replace the existing facility's onsite, stationary (non-transportation) natural gas usage.	therm/yr
EF_{NG}	=	GHG emission factor for natural gas combustion.	$MTCO_2e$/therm

The quantification period is calculated using Equation 12, using a pro-rated operational life which considers how much fuel is expected to be produced during each year of the project by accounting for facility ramp-up and uptime. Due to the uncertainty of how long the project facility may actually remain operational, quantification of total potential emission reductions for the project is limited to a maximum of 5 years.

Equation 12: Quantification Period

$$Q = \left(\sum_{yr=1}^{L} OC_{yr} \right) \times U$$

Where,			Units
Q	=	Quantification period for the production of the primary fuel, secondary fuel, tertiary fuel, renewable electricity, and renewable natural gas.	Years
OC	=	Operating capacity over a particular year of the facility's operational life, for the primary fuel, secondary fuel, tertiary fuel, renewable electricity, and renewable natural gas.	% Year
U	=	Annual facility uptime, defined as the percentage of days in a 365 day calendar year that the facility is expected to be operating, taking into consideration planned maintenance and other potential shutdowns.	%
L	=	The project life, up to 5 years.	[unitless]

2. Criteria and Toxic Air Pollutant Emission Reduction Equations

The criteria and toxic air pollutant co-benefits are estimated as the difference between emissions in the baseline and project scenarios. Emissions are calculated based on alternative fuel production and consumption, avoided baseline fuel consumption, avoided electricity usage, and avoided natural gas usage, multiplied by the appropriate emission factor. Emission reductions that occur at or near the project site are considered "local" (e.g., facility operations, offset of natural gas usage), while emission reductions distributed throughout the State are considered "remote" (e.g., vehicle fuel consumption, offset of electricity usage). Equation 13 through Equation 26 show how criteria and toxic emissions (ROG, NOx, $PM_{2.5}$, and PM_{10}) are calculated in the LCFPP

Benefits Calculator Tool. Note that positive values correspond to emission reductions, while negative values correspond to increases.

Equation 13: Total Criteria and Toxic Air Pollutant Emission Reductions

$$ER_{AP} = LER_{AP} + RER_{AP}$$

Where,			Units
ER_{AP}	=	Total air pollutant emission reductions from the project.	lb
LER_{AP}	=	Total local air pollutant emission reductions from the project.	lb
RER_{AP}	=	Total remote air pollutant emission reductions from the project.	lb

Local air pollutant emission reductions are calculated using Equation 14, which include emission reductions from onsite natural gas savings, improvements to dairy solid separation and lagoon systems (if applicable); as well as emission increases from fuel distribution, onsite natural and renewable natural gas usage, and transporting raw biogas (if applicable).

Equation 14: Local Criteria and Toxic Air Pollutant Emission Reductions

$$LER_{AP} = \left(AAE_{AP,NG\ Sav} \times L\right) - \left(AE_{AP,NG} \times Q\right) - \left(AE_{AP,RNG} \times Q_{RNG}\right) + \left(AAE_{AP,SS} \times L\right) + \left(AAE_{AP,Lagoon} \times L\right) - \left(AE_{AP.Biogas} \times Q\right)$$

Where,			Units
LER_{AP}	=	Total local air pollutant emission reductions from the project.	lb
$AAE_{AP,\ NG\ Sav}$	=	Annual avoided air pollutant emissions from reduced use of natural gas for an existing facility's stationary applications.	lb/yr
$AE_{AP,\ NG}$	=	Annual air pollutant emissions from the increased use of natural and renewable natural gas for the project.	lb/yr
$AE_{AP,\ RNG}$	=	Annual air pollutant emissions from use of renewable natural gas produced by project for onsite electricity generation for stationary end use.	lb/yr
$AAE_{AP,\ SS}$	=	Annual avoided air pollutant emissions from changes to the dairy solid separation systems, if applicable.	lb/yr
$AAE_{AP,\ Lagoon}$	=	Annual avoided air pollutant emissions from changes to the dairy lagoon system, if applicable.	lb/yr
$AE_{AP,\ Biogas}$	=	Annual air pollutant emissions from the transport or raw biogas from a dairy cluster to a central processing facility, if applicable.	lb/yr
Q	=	Quantification period for the production of the primary fuel, secondary fuel, tertiary fuel, or renewable natural gas, up to 5 years.	Years
L	=	The project life, up to 5 years.	[unitless]
i	=	Primary, secondary, or tertiary transportation fuel.	[unitless]
n	=	Number of types of transportation fuels expected to be produced by the project, up to three.	[unitless]

Equation 15: Local Criteria and Toxic Air Pollutant Emission Reductions from Reduced Onsite Use of Natural Gas

$$AAE_{AP,NG\ Sav} = S_{NG} \times EF_{AP,NG}$$

Where,			Units
$AAE_{AP,\ NG\ Sav}$	=	Annual avoided air pollutant emissions from reduced use of natural gas for an existing facility's stationary applications.	lb/yr
S_{NG}	=	Annual onsite, stationary (non-transportation) natural gas savings.	therm/yr
$EF_{AP,\ NG}$	=	Air pollutant emission factor for natural gas combustion.	lb/therm

Equation 16: Local Criteria and Toxic Air Pollutant Emissions from Natural and Renewable Natural Gas Usage

$$AE_{AP,NG} = U_{NG} \times EF_{AP,NG}$$

Where,			Units
$AE_{AP,\ NG}$	=	Annual air pollutant emissions from the increased use of natural and renewable natural gas for the project.	lb/yr
U_{NG}	=	Annual onsite, stationary (non-transportation) natural gas consumption.	therm/yr
$EF_{AP,\ NG}$	=	Air pollutant emission factor for natural gas combustion.	lb/therm

Equation 17: Local Criteria and Toxic Air Pollutant Emissions from Renewable Natural Gas Usage for Electricity Generation

$$AE_{AP,RNG} = P_{RNG\ Gen} \times R_{Onsite} \times EF_{AP,Tech}$$

Where,			Units
$AE_{AP,\ RNG}$	=	Annual air pollutant emissions from the use of renewable natural gas produced by the project for onsite electricity generation for stationary applications.	lb/yr
$P_{RNG\ Gen}$	=	Estimated annual renewable natural gas production at full production capacity.	therm/yr
R_{Onsite}	=	The percentage of renewable natural gas produced by the project for stationary applications that will be used onsite.	%
$EF_{AP,\ Tech}$	=	Air pollutant emission factor for the electricity generation equipment.	lb/therm

Equation 18: Local Criteria and Toxic Air Pollutant Emission Reductions from Improved Solid Separation at Dairies

$$AAE_{AP,SS} = \left\{ \left[\sum_{Cow\ Type} \left(Cow_{baseline} \times VS_{Land,baseline,1}\right) \times \left(1 - TCE_{baeline,1}\right) + \sum_{Cow\ Type} \left(Cow_{baseline} \times VS_{Land,baseline,2}\right) \times \left(1 - TCE_{baeline,2}\right) \right] - \left[\sum_{Cow\ Type} \left(Cow_{baseline} \times VS_{Land,project,1}\right) \times \left(1 - TCE_{project,1}\right) + \sum_{Cow\ Type} \left(Cow_{baseline} \times VS_{Land,project,2}\right) \times \left(1 - TCE_{project,2}\right) \right] \right\} \times EF_{AP,Manure}$$

Where,			Units
$AAE_{AP,\ SS}$	=	Annual avoided air pollutant emissions from changes to the dairy solid separation systems, if applicable.	lb/yr
Cow	=	Number of dairy cattle, before or after project implementation.	head
Cow Type	=	Type of cow (e.g., freestall, open lot corral, dry, and heifers).	[unitless]
VS_{Land}	=	Percent volatile solids deposited on land and not entering wet/anaerobic environment, before or after project implementation.	%
TCE	=	Total control effectiveness of the manure management practice, before or after project implementation.	%
$EF_{AP,\ Manure}$	=	Air pollutant emission factor for manure.	lb/head/year

Equation 19: Local Criteria and Toxic Air Pollutant Emission Reductions from Improved Lagoon System at Dairies

$$AAE_{AP,Lagoon} = \left[\sum_{Cow\ Type} \left(Cow_{baseline} \times VS_{Wet,baseline}\right) - \left(\sum_{Cow\ Type} \left(Cow_{project} \times VS_{Wet,project}\right) \times \left(1 - TCE\right) \right) \right] \times EF_{AP,Manure}$$

Where,			Units
$AAE_{AP,\ Lagoon}$	=	Annual avoided air pollutant emissions from changes to the dairy lagoon system, if applicable.	lb/yr
Cow	=	Number of dairy cattle, before or after project implementation.	head
Cow Type	=	Type of cow (e.g., freestall, open lot corral, dry, and heifers).	[unitless]
VS_{Wet}	=	Percent volatile solids entering the wet/anaerobic system, before or after project implementation.	%
TCE	=	Total control effectiveness of the digester system.	%
$EF_{AP,\ Manure}$	=	Air pollutant emission factor for manure.	lb/head/year

Equation 20: Local Criteria and Toxic Air Pollutant Emissions from Transporting Raw Biogas to a Central Processing Facility

$$AE_{AP.Biogas} = \left(D_{Biogas} \times 2\right) \times T_{Biogas} \times EF_{AP,Biogas\,Trans} \times 0.002205$$

Where,			Units
$AE_{AP,\,Biogas}$	=	Annual air pollutant emissions from the transport or raw biogas from a dairy cluster to a central processing facility, if applicable.	lb/yr
D_{Biogas}	=	Quantification period for the production of the primary fuel, secondary fuel, tertiary fuel, or renewable natural gas.	miles
T_{Biogas}	=	Number of vehicle trips per year required to deliver raw biogas from the production facility to the central processing facility.	trips/year
$EF_{AP,\,Biogas\,Trans}$	=	Air pollutant emission factor for the fuel-specific vehicle used to transport the raw biogas.	g/mile
0.002205	=	Conversion factor from grams to pounds.	lb/g

Equation 21: Remote Criteria and Toxic Air Pollutant Emission Reductions

$$RER_{AP} = \left[\sum_{i=1}^{n}\left(FEF_{AP,baseline,i} - FEF_{AP,alt,i}\right) \times V_i \times C_{Fuel,i} \times Q_i\right] - \left[\sum_{i=1}^{n}\left(AE_{AP,Dist,i}\right) \times Q_i\right] - \left(AE_{AP,Elec} \times L\right) + \left(AAE_{AP,Elec\,Gen} \times Q_{Elec}\right) + \left(AAE_{AP,Elec\,Sav} \times L\right)$$

Where,			Units
RER_{AP}	=	Total remote air pollutant emission reductions from the project.	lb
$FEF_{AP,\,baseline,i}$	=	Average annual avoided air pollutant emissions of the baseline transportation fuel, relative to the corresponding replacement transportation fuel.	lb/yr
$FEF_{AP,\,alt,i}$	=	Average annual air pollutant emissions of the replacement alternative transportation fuel.	lb/yr
V	=	Annual fuel production capacity of the primary fuel, secondary fuel, or tertiary fuel.	[Unit of weight or volume]
$C_{Fuel,\,i}$	=	Conversion factor from unit of annual fuel production capacity to gallons of gasoline or diesel equivalent.	gal/[Unit of weight or volume]
$AE_{AP,\,Dist}$	=	Annual air pollutant emissions from the distribution of the primary, secondary, and tertiary transportation fuel from the production facility to an end destination.	lb/yr
$AE_{AP,\,Elec}$	=	Annual air pollutant emissions from onsite, stationary (non-transportation) grid electricity consumption.	lb/yr
$AAE_{AP,\,Elec\,Gen}$	=	Annual avoided air pollutant emissions from the generation of renewable electricity to displace grid electricity usage for stationary applications.	lb/yr
$AAE_{AP,\,Elec\,Sav}$	=	Annual avoided air pollutant emissions from reduced use of grid electricity for an existing facility's stationary applications.	lb/yr
Q	=	Quantification period for production of the primary fuel, secondary fuel, tertiary fuel, and renewable electricity, up to 5 years.	Years
L	=	Project life, up to 5 years.	Years
i	=	Primary, secondary, or tertiary transportation fuel.	[unitless]
n	=	Number of types of transportation fuels expected to be produced by the project, up to three.	[unitless]

Equation 22: Average Air Pollutant Emissions for Usage of the Baseline and Project Transportation Fuel

$$FEF_{AP} = \frac{\left(EF_{AP,Fuel,Yr\ 1} \times M_{AP,Fuel,Yr\ 1}\right) + \left(EF_{AP,Fuel,Yr\ F} \times M_{AP,Fuel,Yr\ F}\right)}{2} \times C_{AP}$$

Where,			Units
FEF_{APi}	=	Average annual air pollutant emissions from transportation fuel use.	lb/yr
$EF_{AP,\ Fuel,\ Yr1}$	=	Air pollutant emission factor for transportation fuel use corresponding to statewide fleet during the first year of operation.	g/mi
$M_{AP,\ Fuel,\ Yr1}$	=	Fuel economy corresponding to the statewide fleet in during first year of operation.	mi/gal
$EF_{AP,\ Fuel,\ YrF}$	=	Air pollutant emission factor for transportation fuel use corresponding to statewide fleet during the last quantification period year.	g/mi
$M_{AP,\ Fuel,\ YrF}$		Fuel economy corresponding to statewide fleet during the last quantification period year.	mi/gal
C_{AP}	=	Conversion factor from units of grams to pounds.	0.002205 lb/g

Note that the air pollutant emission factors ($EF_{AP,\ Fuel}$) for alternative fuels such as ethanol, biodiesel, and renewable diesel (with the exception of RNG, hydrogen, and electricity) use the same emission factors as their fossil fuel counterpart due to limited data in CARB's Mobile Source Emission Inventory (EMFAC2014).

Equation 23: Remote Criteria and Toxic Air Pollutant Emission Reductions from Distributing Transportation Fuel from the Production Facility to an End Destination

$$AE_{AP,Dist} = \left(\frac{V}{Q_{Veh}}\right) \times (D_{Dist} \times 2) \times EF_{AP,Dist}$$

Where,			Units
V	=	Annual fuel production capacity of the primary fuel, secondary fuel, or tertiary fuel.	[Unit of weight or volume]
Q_{Veh}	=	Quantity of Primary Fuel Transported per Vehicle Trip.	[Unit of weight or volume]/trip
D_{Dist}	=	Distance between the fuel production facility and the end destination for the fuel.	mile
$EF_{AP,\ Dist}$	=	Air pollutant emission factor for the fuel-specific vehicle used to transport fuel from the production facility to the end destination.	lb/yr

For projects that distribute fuel by on-road tanker truck, the emission factor ($EF_{AP,\ Dist}$) is based upon the average statewide population-weighted emission factors for heavy-duty vehicles over the quantification period. For projects that distribute fuel by rail, the emission factor is based upon $EF_{AP,\ Dist}$ the average statewide population-weighted emission factors by tier for short line or line haul locomotives, over the quantification period.

Equation 24: Remote Criteria and Toxic Air Pollutant Emissions from Grid Electricity Usage

$$AE_{AP,Elec} = U_{NG} \times EF_{AP,Elec}$$

Where,			Units
$AE_{AP,\ Elec}$	=	Annual air pollutant emissions from onsite stationary (non-transportation) electricity consumption.	lb/yr
U_{Elec}	=	Annual onsite, stationary (non-transportation) grid electricity consumption.	kWh/yr
$EF_{AP,\ Elec}$	=	Criteria and toxic emission factor for California's electrical grid.	lb/kWh

Equation 25: Remote Criteria and Toxic Air Pollutant Emission Factor for Renewable Electricity Generation

$$AAE_{AP,Elec\ Gen} = EF_{AP,Grid} \times P_{Elec\ Gen}$$

Where,			Units
$AAE_{AP,\ Elec\ Gen}$	=	Annual avoided air pollutant emissions from the generation of renewable electricity to displace grid electricity usage for stationary applications.	lb/yr
$EF_{AP,\ Grid}$	=	Criteria and toxic emission factor for California's electrical grid.	lb/kWh
$P_{Elec\ Gen}$	=	Estimated annual renewable electricity generation at full production capacity.	kWh/yr

Equation 26: Remote Criteria and Toxic Air Pollutant Emission Factor for Electricity Savings

$$AAE_{AP,Elec\ Sav} = EF_{AP,Grid} \times P_{Elec\ Sav}$$

Where,			Units
$AAE_{AP,\ Elec\ Sav}$	=	Annual avoided air pollutant emissions from reduced use of grid electricity for an existing facility's stationary applications.	lb/yr
$EF_{AP,\ Grid}$	=	Criteria and toxic emission factor for California's electrical grid.	lb/kWh
$P_{Elec\ Sav}$	=	Estimated annual reduction in existing facility operation's electricity consumption, at full production capacity.	kWh/yr

B. Calculation of Other Reported Metrics

In addition to a calculation of the total GHG and air pollutant emission reductions, the LCFPP Calculator Tool also computes the following co-benefits:

- Fossil Fuel Use Reductions (gallons)
- Renewable Fuel Production (gallons)
- Fossil Fuel Energy Use Reductions (kWh or therm)
- Renewable Energy Generation (kWh)
- Material Diverted from Landfill (tons)
- Water Savings (gallons)

Fossil Fuel Use Reductions and Renewable Fuel Production are calculated on a raw gallon basis. CNG, RNG, and hydrogen are converted to their petroleum gallon equivalent.

Section C. References

The following references were used in the development of this Quantification Methodology and the LCFPP Benefits Calculator Tool.

California Air Resources Board. (2019). CA-GREET 3.0. https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

California Air Resources Board. (2018). California Climate Investments Quantification Methodology Emission Factor Database. http://www.arb.ca.gov/cci-resources

California Air Resources Board. (2017). 2017 Emissions Inventory Aggregated at County/Air Basin/State for Line Haul Locomotives. https://www.arb.ca.gov/msei/ordiesel/locolinehaul2017ei.xlsx

California Air Resources Board. (2017). 2017 Short line Rail Emissions Model. https://www.arb.ca.gov/msei/ordiesel/locoshortline2017ei.docx

California Air Resources Board. (2014). EMFAC2014 Web Database. https://www.arb.ca.gov/emfac/2014/

San Joaquin Valley Air Pollution Control District. (2012). Air Pollution Control Officer's Revision of the Dairy VOC Emission Factors. https://www.valleyair.org/busind/pto/emission_factors/2012-Final-Dairy-EE-Report/FinalDairyEFReport(2-23-12).pdf

South Coast Air Quality Management District. (2004). Final Staff Report Proposed Rule 1127 – Emission Reductions from Livestock Waste. http://www.aqmd.gov/docs/default-source/rule-book/support-documents/rule-1127/final-staff-report.pdf

UC Davis Biomass Collaborative, U.S. EPA Region 9, and National Risk Management Research Lab Office of Research and Development. (September 2016). Evaluating the Air Quality, Climate & Economic Impacts of Biogas Management Technologies. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=335668&Lab=NRMRL